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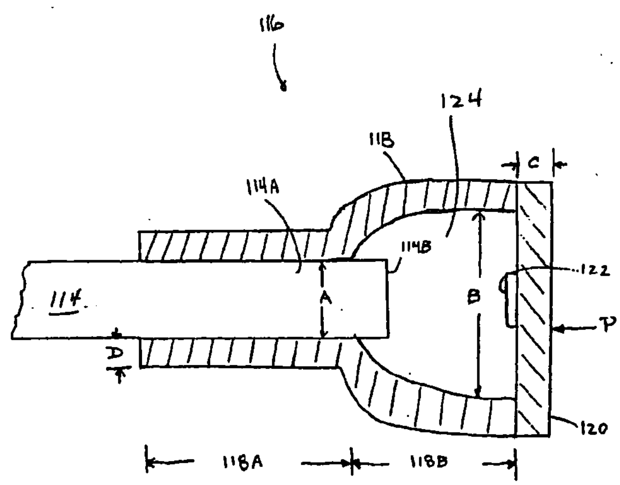

(57) Abstract: A fiber-optic pressure sensor apparatus includes a section of optical fiber coupled to an interferometer sensor tip having a structure made almost entirely of silicon. The tip structure includes a thin diaphragm bonded to a tip body. The tip body is bell-shaped in a sectional view and includes a curved cross-sectional shape and includes a fiber grip portion which holds a distal end of the optical fiber and a diaphragm support portion to which is bonded the diaphragm. The diaphragm includes a reflective film which is separated from an end surface of the optical fiber to define an interference cavity. The diaphragm deforms or deflects in response to a pressure difference from one side to the other. The movement of the diaphragm alters the optical path length of the interference cavity. The combination of reflections from the two surfaces of the interference cavity provides a standard optical interference signal for measurement by a measurement apparatus.

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FIBER OPTIC PRESSURE SENSOR

BACKGROUND OF THE INVENTION

Sensors are used to measure different types of parameters such as temperature, acceleration, pressure, and flow. Interferometers have been used in some sensors for measuring these different parameters. An example of an interferometer is a Fabry-Perot interferometer, which has two partially reflective surfaces that are separated from one another in an interference cavity. The parameter to be measured is operably coupled to one or both of the reflective surfaces such that a change in the parameter changes the distance between the surfaces or the optical properties of the media between the surfaces. The interferometer measures the distance between the reflective surfaces based on interference between light reflecting from the reflective surfaces. A variety of different interferometric sensors make use of this principle.

SUMMARY OF THE INVENTION

In accordance with the present invention, a fiber optic pressure sensor apparatus includes a section of optical fiber coupled to an interferometer sensor tip having a structure made almost entirely of silicon. The tip structure includes a thin diaphragm bonded to a tip body. The tip body is bell-shaped in a sectional view and includes a curved cross-sectional shape. The tip body includes a fiber grip portion which holds a distal end of the optical fiber and a diaphragm support portion to which is bonded the diaphragm. A reflective film is provided on the diaphragm which is separated from an end surface of the optical fiber to define an interference cavity. The diaphragm deforms or deflects in response to a pressure difference from one side to the other. The movement of the diaphragm alters the optical path length of the interference cavity. The combination of reflections from the two surfaces of

the interference cavity provides a standard optical interference signal for measurement by a measurement apparatus.

In an embodiment, the tip body is substantially round in cross-sectional shape and is monocrystalline silicon. The bond of the diaphragm to the support is monolithic, i.e., inorganic and chemically bonded, and can be monocrystalline.

The present invention includes a method for fabricating a sensor tip structure. The method includes fabricating a tip body from a first silicon wafer and a diaphragm from a second silicon wafer. The method further includes bonding the diaphragm to the tip body to form the sensor tip structure. In the first silicon wafer, cylindrical bores are formed to match an optical fiber diameter using a process such as Deep Reactive Ion Etch (DRIE). Cavities sized to match a diaphragm diameter are aligned to the bores on the opposite surface of the first wafer and etched to meet the bores.

The first wafer is subjected to boron diffusion such that the silicon surrounding the cavities and bores attains a boron doping level (e.g., above 5×10^{19} atom/cc) to a distance from the cavities equal to the desired wall thickness of the structure.

A second silicon wafer is diffused on one surface with boron to the same concentration to a depth equal to the desired diaphragm thickness. The second wafer is then bonded to the diaphragm by bonding the second wafer to the first wafer. This bond can be a "direct wafer bond", silicon to silicon, or can incorporate a hard, high-temperature material, such as silicon dioxide or a precious metal. A reflective film is deposited (sputtered or evaporated) through the holes through the perforated wafer onto the diaphragm.

The wafer bearing the diaphragm is etched in a selective etchant that leaves the highly doped diaphragm layer. This layer is photo-patterned to define the portions to be used in the finished parts, that is, freed diaphragms and rims bonded to the highly-boron-doped portion of the first wafer. Unwanted diaphragm material is etched away, along with underlying bonding material (if any is used). All of the un-doped portion of the first wafer is etched away in the selective etchant, and the parts fall free.

An alternate approach to fabricating the sensor tip structure uses an electrochemical etch stop and a conductive bond between wafers.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

FIG. 1 is a schematic representation of a sensor system in accordance with an embodiment of the present invention.

FIG. 2 is a sectional view of an embodiment of the sensor tip of FIG. 1.

FIG. 3 is a process sequence for a method of fabricating the sensor tip of FIG. 2.

FIG. 4 is a sectional view of another embodiment of the sensor tip of FIG. 1.

FIG. 5 is a perspective view of yet another embodiment of the sensor tip of FIG. 1.

FIG. 6 is a partial sectional view of the sensor tip of FIG. 5.

FIG. 7 is a plot of applied pressure versus deflection of the diaphragm of the sensor tip of FIGS. 5 and 6.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a schematic representation of a sensor system 100 according to one embodiment of the present invention. Sensor system 100 includes measurement apparatus 102 and sensor apparatus 104. Measurement apparatus 102 includes light or optical source 106, beam splitter 108, optical detector 110 and processor 112. Sensor apparatus 104 includes optical fiber 114 coupled to interferometer sensor tip 116.

FIG. 2 is a sectional view of an embodiment of the sensor tip 116 of FIG. 1. The sensor tip 116 includes tip body 118 and diaphragm 120. The tip body 118 has

a fiber grip portion 118A which holds a distal end 114A of optical fiber 114 and a diaphragm support portion 118B to which the diaphragm 120 is bonded. A reflective film or surface 122 is provided on the diaphragm 120 and is separated from an end surface 114B of the optical fiber 114 to define an interference cavity 124. The diaphragm 120 bonded to the support portion 118B forms a fixed-edge diaphragm.

The sensor tip body 118 which is bonded to the diaphragm can have the same thermal expansion as the diaphragm to avoid thermal shift of sensitivity or buckling. The sensor tip body 118 has an inner diameter A sized to receive the distal end 114A of the optical fiber. The fiber end is positioned to a set distance in the body 118 and then permanently sealed. The diaphragm 120 has a free area diameter B and a thickness C. The wall thickness D of the tip body 118 in one embodiment is selected to be not less than approximately three times the diaphragm thickness D. In an embodiment of a sensor tip 116 fabricated for handling measurements specified for 200 mmHg (4 psi) and 8 nm/mmHg deflection, for example, typical dimensions are A=150 μm; B=300 μm; C=7 μm and D=21 μm.

Referring now to both FIG. 1 and FIG. 2, light from the light source 106 is introduced into the optical fiber 114 through beam splitter 108 and in the direction of the sensor tip 116. A pressure P applied to the surface of diaphragm 120 causes the diaphragm to deform which alters the optical path length of interference cavity 124. Optical fiber 114 transmits reflected light from the surface of reflective film 122 and from the end surface 114B back toward the beam splitter 108 of measurement apparatus 102. The combination of reflections from the two surfaces provides a standard optical interference signal. The splitter 108 directs a portion of the reflected light to optical detector 110 which detects the optical interference signal for conventional processing by processor 112.

A process sequence for a method of fabricating the sensor tip 116 is now described with reference to FIG. 3.

1. A wafer 200 of silicon enters the process lightly doped and with a thick coating of oxide 202 on a first side 204 and a second side 206.

2. Onto the first side 204 of the wafer 200 a pattern of openings 208 is defined with photoresist and etched through the oxide 202 to the silicon. These openings 208 are sized with reference to the optical fiber so that resulting holes 210 can provide a snug fit to the optical fiber.
3. Using Deep Reactive Ion Etch (DRIE) the exposed silicon is etched to a depth slightly less than the thickness of the wafer, with the walls of the holes 210 very nearly cylindrical. In an alternate embodiment, the holes can be made using impact grinding or electrical discharge machining (EDM). However, DRIE provides better fine dimensional control.
4. The wafer 200 is thermally oxidized to line the holes 210 with silicon dioxide 212.
5. On the second side 206 of the wafer 200, masked photoresist and etchant are used to make openings 214 in the oxide 202 aligned to the deep holes 210 in the first side 204.
6. Through the openings 214 in the second side 206, an isotropic (rounding) etchant is used to form a cavity 216 which extends into the wafer 200 to engage the holes 210 from the first side 204. This etching is continued until the surface diameter of the etched cavity 216 reaches the required inside diameter of the bonded diaphragm of the completed device.
7. The silicon dioxide lining 212 of the first-side holes 210 is removed by protecting the second-side oxide, masking the first side with a dry-film resist, and re-applying the mask pattern of step 2. A plasma or vapor etchant is preferred for action at the bottom of the deep holes 210.
8. The wafer 200 is subjected to a long boron diffusion 218, such that the exposed silicon (the bores of the holes) has its boron concentration brought above $5x10^{19}$ boron/cc to a distance from the hole bore equal to the desired wall thickness of the finished part. The oxide on the second side 206 is then patterned. The oxide on the first side 204 is protected and a dry-film resist is used with a mask to protect a ring 220 of oxide around each second-side hole 214, the other oxide on the second side 206 being removed.

9. The wafer 200 ready to accept diaphragms has oxide on the first side 204, oxide rings 220 around holes 214 on the second side 206, and diffusion-lined through-holes 210.
10. A diaphragm wafer 300 is prepared. A silicon wafer 300 with oxide 302 on its backside 306 is diffused to bring the boron concentration above 5×10^{19} boron/cc to a depth equal to the thickness of the desired diaphragm. The diffusion operation will leave on the diffused side 304 a mixed oxide 318 of silicon and boron which will have a softening temperature much lower than that of silicon dioxide.
11. The second side 206 of the first wafer 200 and the diffused side 304 of the second wafer 300 are pressed together and heated to make a bond. Typical conditions are, for example, 2,585 mmHg (50psi) squeeze, 800^0C for 1 hour. In this embodiment, no alignment of the wafers 200, 300 is needed. However, if the diaphragm includes corrugations (see below), then alignment of the wafers 200, 300 is necessary.
12. The oxide 302 is removed from the backside 306 of the second wafer 300.
13. The assembly is etched in an etchant sensitive to boron concentration (EDP) to remove all of the second wafer 300 except that top layer having high boron concentration.
14. Photoresist masking is aligned onto the remains of the second wafer 300 to protect only the diaphragms 308 of the sensors, other thin silicon being etched away.
15. Reflective metal film 310 is deposited (e.g., from a point source) onto the first surface 204 of the first wafer 200. Precious metals (e.g., gold), which are resistant to EDP etchant, are preferred. As reflectance is needed on the inside of the diaphragm 308, at the bottom of a deep hole 210, either a directional evaporation can be used, or a substantial excess sputtered onto the surface with the openings, leaving a metal film 312 on the diaphragm.
16. The excess metal 310 and the oxide are removed from the first surface 204 of the first wafer 200.

17. The wafer 200 is etched with the doping sensitive etchant, dissolving all undoped silicon. The tip parts 400 comprising oxide and highly doped silicon fall free into the etchant. They must be retrieved from the etchant and rinsed clean.

The parts are slipped onto the end of the fiber, the designed spacing of reflective spot from fiber end is found, and the parts are cemented and sealed to the fiber.

The above describes a diaphragm that is formed using a diffusion layer doped to etch-resistance with boron. In an alternate embodiment, the diaphragm can be an epitaxial layer grown on the second wafer. An epitaxial layer is smooth enough so that direct silicon to silicon atomic bonding can be accomplished. Diffusion generally roughens the surface enough that an oxide-bonding operation is required. Either way, a very strong "monolithic" bond can be made. In any of the embodiments, the diaphragm can be atomically bonded to the tip body.

In an embodiment, the sensor tip is cemented to the end of an optical fiber with a dry gas between the diaphragm and the fiber end, thereby making a "sealed" transducer. In another embodiment, the device is sealed with vacuum inside it to provide an "absolute" transducer. In still another embodiment as shown in FIG. 4, a "gage" transducer 401, open to ambient pressure, can be made by providing a vent tube 402 (e.g., very fine Pyrex tubing) to a reference pressure site. The vent access is provided between the optical fiber 114 and the edge of the active diaphragm 120.

The sensor tip embodiments described above can be readily and economically fabricated.

Linearity of deflection can be improved by corrugating the edge of the diaphragm. If the diaphragm is formed by diffusion, adding corrugations to the surface before diffusion is easy. However, it is important that the corrugations on the diaphragm wafer be aligned to the holes in the body wafer for bonding. FIG. 5 is a perspective view of a sensor tip 116 wherein the diaphragm 120 is corrugated to improve the linearity of response of the diaphragm. More particularly, the corrugations extend the surface length of the diaphragm which softens the extension effect on deflection.

FIG. 6 is a partial cross-sectional view of the sensor tip 116 of FIG. 5. In this embodiment, the diaphragm 120 has a thickness of about 2.4 μm. The outer diameter 602 of the tip body 118 is about 350 μm. The diaphragm 120 in this embodiment has a plurality of alternating ridges 604 and grooves 606 to form the corrugated surface. Only three ridges 604 are shown, but it is understood that more or less ridges and grooves can be implemented in accordance with the present invention. The distance 608 between ridges 604 is about 14.24 μm. The walls 610, which connect the ridges 604 to the grooves 606, can have an angle α in the range of between about 45 degrees and 54.7 degrees. The distance 612 from the groove 606 to the ridge 604 can be about 5 μm. The width 614 of the opening of each corrugation can be about 12 μm.

To incorporate corrugations in the diaphragm, the corrugations are formed into the surface of the wafer which is to become the diaphragm. In one embodiment, the surface of the wafer is first coated with oxide. A pattern of rings corresponding to the corrugations is photolithographically opened in the oxide. With the oxide as a mask, an isotropic etchant is used to etch grooves into the surface to the desired height of the corrugations. The oxide mask is then removed. From here on, the process is the same as for the plane diaphragm, doping to the desired thickness of etch-resistant material, etc. When the two wafers are assembled, the corrugations can be aligned coaxial with the fiber port in the body. Special alignment features can be provided at the margins of the wafers to facilitate alignment.

FIG. 7 is a plot of applied pressure, measured in torr, versus deflection, measured in micrometers, of the center of the diaphragm 170 of the sensor tip of FIGS. 5 and 6. The sensitivity of deflection is 0.902 μm/atm or 11.868 Å/torr.

In another embodiment, a boss is formed at the diaphragm center so that the reflecting surface remains more nearly flat than the flexing part of the diaphragm.

The above processes (FIG. 3) for fabricating the sensor tip are in context of differentiation of the desired parts (i.e., tip body and diaphragm) from their respective silicon matrix. An alternate process can be used to differentiate the desired parts from their matrix wafers. This approach uses an electrochemical etch stop. In an appropriate etchant and with an appropriate difference of electrical

potential, P-type silicon can be consumed and N-type silicon conserved. The diaphragm and the tip body are biased, with the bond between wafers a conductive bond rather than the oxide bond described above and shown in FIG. 3.

In this alternate approach, the starting material is P-type silicon. The long bore and the diaphragm are made as described above using two wafers. The inside diameters are diffused with phosphorus or other N-type dopant to place the P/N junction at the desired wall thickness. Similarly, the diaphragm thickness is defined by an N diffusion into its P-type matrix wafer 300. All of the N-type material to be preserved is held with the specified bias with respect to the final etchant and is connected together until removed from the etchant. This can be achieved by diffusing the N dopant into all of the top surface of the first matrix wafer 200. At the end of the etching operation, the parts (i.e., tip body and diaphragm) stand as a forest on this thin layer of N-silicon and are harvested using a separating operation. To form the connection, the reflective metal film 310 is continued across the wafer surface 204 and down into the holes in oxide 202 to provide a conductor. At the end of the electrochemical etching the parts remain standing on a layer of oxide and metal. Dissolution of the oxide permits easy separation.

In alternative embodiments, the thickness of the diaphragm 120 can be defined by use of commercially available SOS (Silicon-Oxide-Silicon) wafers, using the thinner layer of silicon to become the diaphragm. The diaphragm 120 can also be formed as a layer of polycrystalline silicon formed on an oxided silicon wafer.

To attach the diaphragm 120 to the tip body 118 in alternative embodiments, atomic bonding can be used, for example, oxide to silicon, or silicon to silicon to form a monocrystalline silicon structure. Alternatively, various metals can be used to facilitate bonding yet still forming a hard, stable, inorganic bond. One such material is the boron-rich silicon oxide left from the boron diffusion of the diaphragm 120. Another material can include a thin sputtered film of glass, such as Pyrex glass, to facilitate the formation of an anodic bond. Yet another material can include gold, which will alloy with the silicon on both sides of the bond, to form a hard gold-silicon alloy. Several systems of metal films permit hard-soldering across the bond.

In any of the above-disclosed embodiments, the sensor tip can be mass produced thereby saving manufacturing costs.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

CLAIMS

What is claimed is:

1. A sensor tip for use with a fiber optic pressure sensor comprising:

a tip body having a first end and a second end, the first end for receiving an optical fiber, the tip body including a curved cross-sectional shape; and

a diaphragm disposed at the second end of the tip body, wherein the tip body and the diaphragm comprise silicon.

2. The sensor tip of Claim 1, wherein the silicon includes monocrystalline silicon.

3. The sensor tip of Claim 1, wherein the silicon is doped with boron.

4. The sensor tip of Claim 1, wherein the sensor tip is monolithic.

5. The sensor tip of Claim 1, wherein the diaphragm is corrugated.

6. The sensor tip of Claim 1, further comprising a reflective surface disposed on the diaphragm.

7. The sensor tip of Claim 6, further comprising an optical fiber attached to the first end of the tip body, wherein the reflective surface is separated from an end surface of the optical fiber to define an interference cavity within the tip body.

8. The sensor tip of Claim 1, wherein the tip body is bell-shaped in a sectional view.

9. The sensor tip of Claim 1, wherein the tip body and the diaphragm are atomically bonded together.

10. The sensor tip of Claim 1, wherein the tip body and the diaphragm are bonded together with an oxide.

11. The sensor tip of Claim 1, wherein the tip body and the diaphragm are bonded together with a metal.

12. The sensor tip of Claim 11, wherein the metal includes silicon oxide, glass, or gold.

13. The sensor tip of Claim 1, wherein the cross-sectional shape is substantially round.

14. A sensor tip for use with a fiber optic pressure sensor, comprising:

a tip body having a first end and a second end, the first end for receiving an optical fiber, the tip body having a substantially round cross-sectional shape; and

a diaphragm bonded to the second end of the tip body, wherein the tip body and diaphragm include monocrystalline silicon doped with boron.

15. The sensor tip of Claim 14, further comprising a reflective film disposed on the diaphragm and an optical fiber attached to the first end of the tip body, the reflective film separated from an end surface of the optical fiber to define an interference cavity within the tip body.

16. The sensor tip of Claim 14, wherein the diaphragm is corrugated.

17. The sensor tip of Claim 14, wherein the diaphragm is atomically bonded to the tip body.

18. The sensor tip of Claim 14, wherein the tip body and the diaphragm are bonded together with a metal.

19. A sensor tip for use with a fiber optic pressure sensor, comprising:

    a tip body having a first end and a second end, the first end for receiving an optical fiber, the tip body having a curved cross-sectional shape; and

    a diaphragm atomically bonded to the tip body.

20. The sensor tip of Claim 19, wherein the tip body and the diaphragm include monocrystalline silicon doped with boron.

21. The sensor tip of Claim 19, wherein the tip body and the diaphragm are formed from a pattern etch process.

22. The sensor tip of Claim 19, further comprising a reflective surface disposed on the diaphragm and an optical fiber attached to the first end of the tip body, the diaphragm being separated from an end surface of the optical fiber to define an interference cavity within the tip body.

23. The sensor tip of Claim 22, further comprising a vent tube in communication with the interference cavity.

24. The sensor tip of Claim 23, further comprising a transducer disposed within the vent tube.

25. The sensor tip of Claim 19, wherein the cross-sectional shape is substantially round adjacent the diaphragm.

26. A method of forming a sensor tip for use with a fiber optic pressure sensor, comprising:

forming an inorganic tip body having a first end and a second end, the first end for receiving an optical fiber, the tip body having a curved cross-sectional shape; and

bonding an inorganic diaphragm to the second end of the tip body.

27. The method of Claim 26, further comprising forming the tip body and the diaphragm using a pattern etch process.

28. The method of Claim 26, wherein the tip body and the diaphragm include monocrystalline silicon doped with boron.

29. The method of Claim 26, further comprising forming a reflective film on the diaphragm.

30. The method of Claim 26, further comprising attaching an optical fiber to the first end of the tip body, wherein forming a tip body includes forming in a first side of a first silicon wafer a cylindrical bore to match a diameter of the optical fiber and forming in a second side of the first silicon wafer a cavity to match a diaphragm diameter and aligned with the bore.

31. The method of Claim 30, wherein the bore is formed using deep reactive ion etch and the cavity is formed using an isotropic rounding agent.

32. The method of Claim 30, wherein the bore is formed using impact grinding.

33. The method of Claim 30, wherein the bore is formed using electrical discharge machining.

34. The method of Claim 30, wherein forming a tip body further includes subjecting the first silicon wafer to a boron diffusion such that the silicon

surrounding the bore and the cavity attains a predetermined boron doping level to a distance equal to a desired tip body thickness.

35. The method of Claim 34, further comprising forming the diaphragm by subjecting a first surface of a second silicon wafer to a boron diffusion such that the silicon surrounding the first surface attains a predetermined boron doping level to a distance equal to a desired diaphragm thickness.

36. The method of Claim 35, further comprising depositing a reflective film through the bore into the diaphragm.

37. The method of Claim 36, further comprising removing undoped portions of the first and second silicon wafers using a selective etchant.

38. A sensor tip formed by the method of Claim 26.

39. The method of Claim 26, further comprising forming a corrugated surface in the diaphragm.

40. A method of forming a sensor tip for use with a fiber optic pressure sensor, comprising:

defining a tip body by forming tip body interior dimensions and setting tip body wall thickness using compositional change in a surrounding matrix;

defining a diaphragm by compositional change in a supporting matrix;

bonding the diaphragm to the tip body; and

removing the unmodified portions of the matrices.

41. A method of forming a sensor tip for use with a fiber optic pressure sensor comprising atomically bonding a diaphragm to a second end of a tip body

having a curved cross-sectional shape, a first end of the tip body being formed to receive an optical fiber.

42. A method of mass producing sensor tips for use with fiber optic pressure sensors, comprising:

forming a plurality of monocrystalline silicon tip bodies by a pattern etch process;

forming a plurality of monocrystalline silicon diaphragms; and

atomically bonding the diaphragms to the tip bodies.

43. The method of Claim 42, further comprising the step of depositing a reflective film on each diaphragm.

44. The method of Claim 42, further comprising forming a corrugated surface on each diaphragm.

45. A sensor tip for use with a fiber optic pressure sensor, comprising:

a tip body having a first end and a second end, the first end being attached to an optical fiber, the body including a curved cross-sectional shape; and

a diaphragm disposed at the second end of the tip body, wherein the tip body and the diaphragm are formed from an inorganic material.

46. A method of forming a sensor tip for use with a fiber optic pressure sensor, comprising:

forming an inorganic tip body that includes a curved cross-sectional shape;

attaching an optical fiber to a first end of the tip body; and

bonding an inorganic diaphragm to a second end of the tip body.

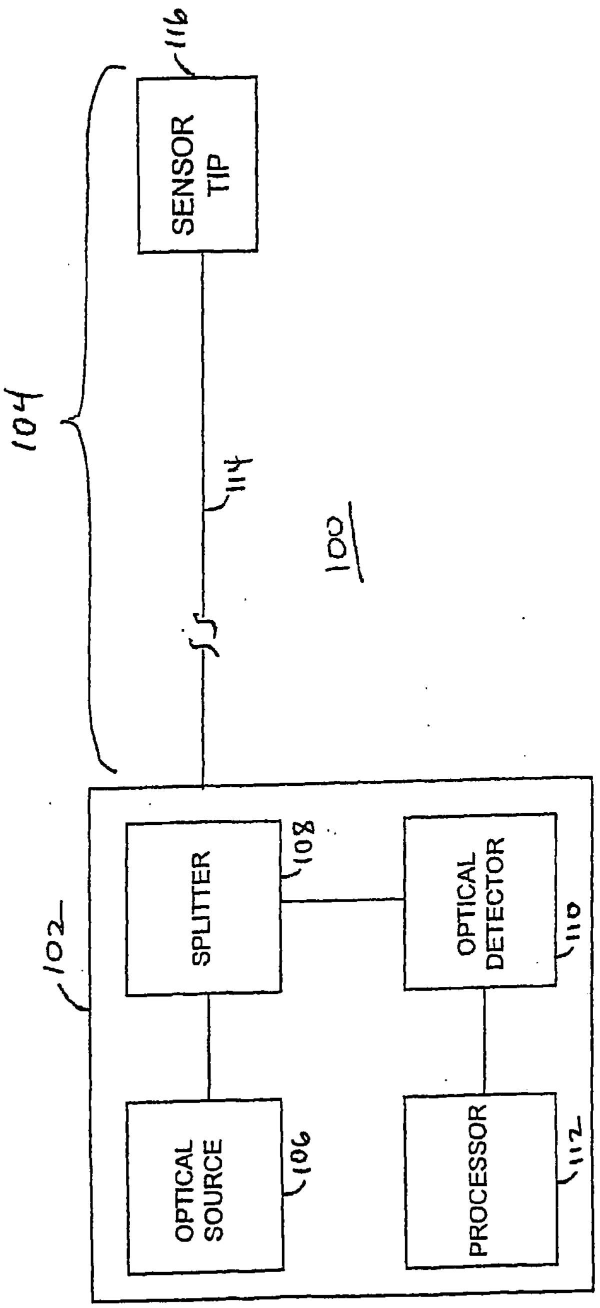

SENSOR TIP
116
104
114
100
SPLITTER
108
OPTICAL DETECTOR
110
102
OPTICAL SOURCE
106
PROCESSOR
112

FIG. 1

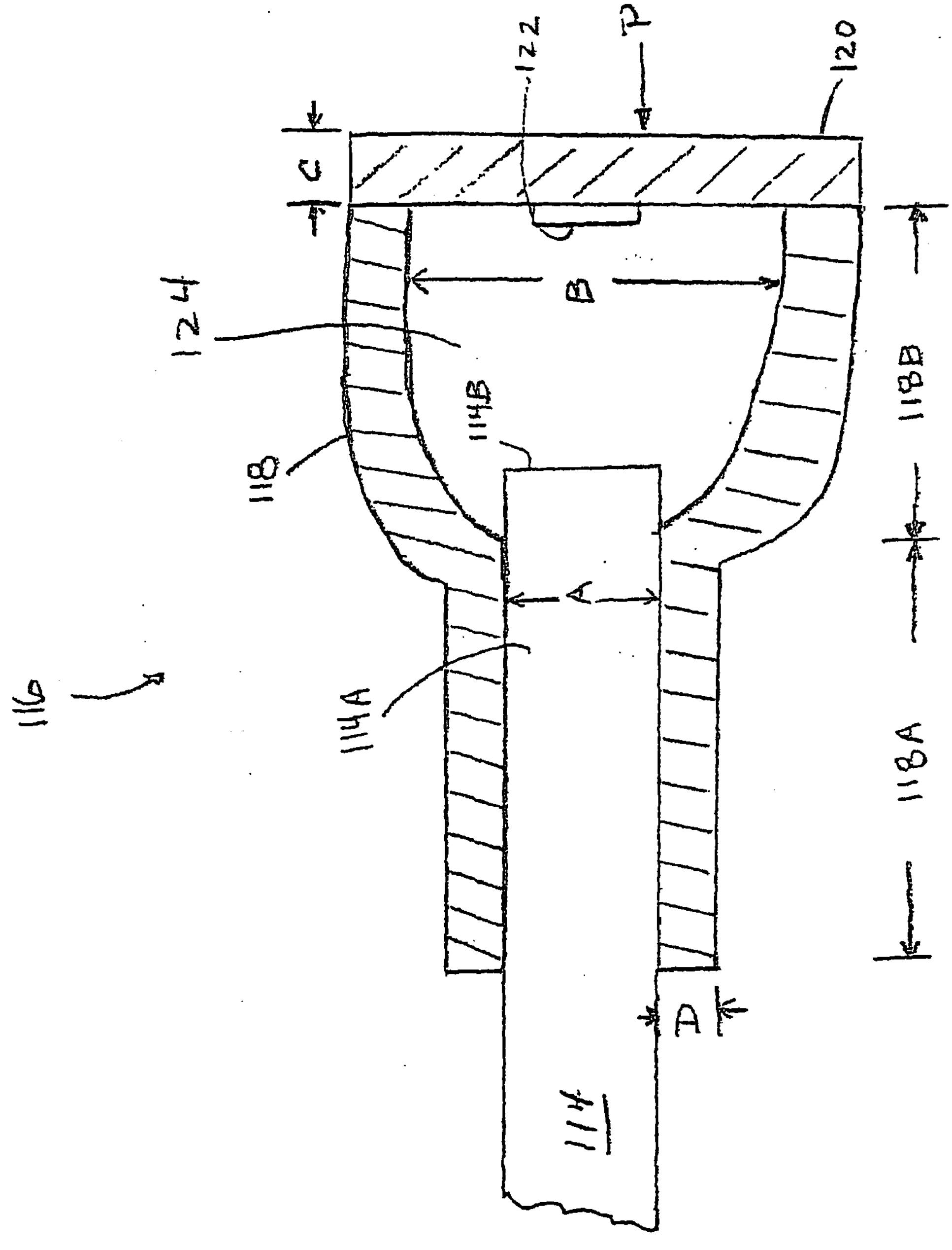
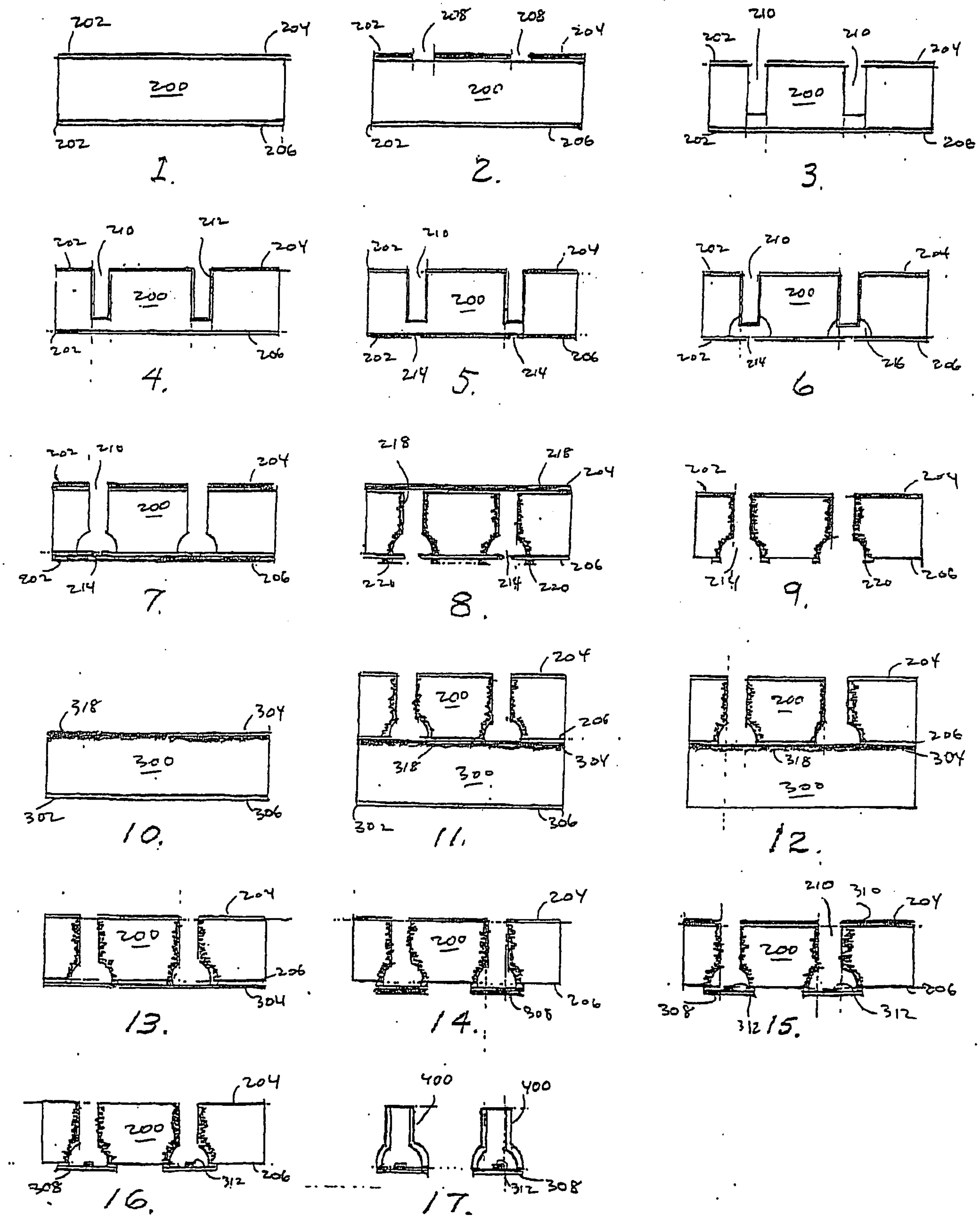


FIG. 2

FIG. 3

SILICON PROCESSING SEQUENCE



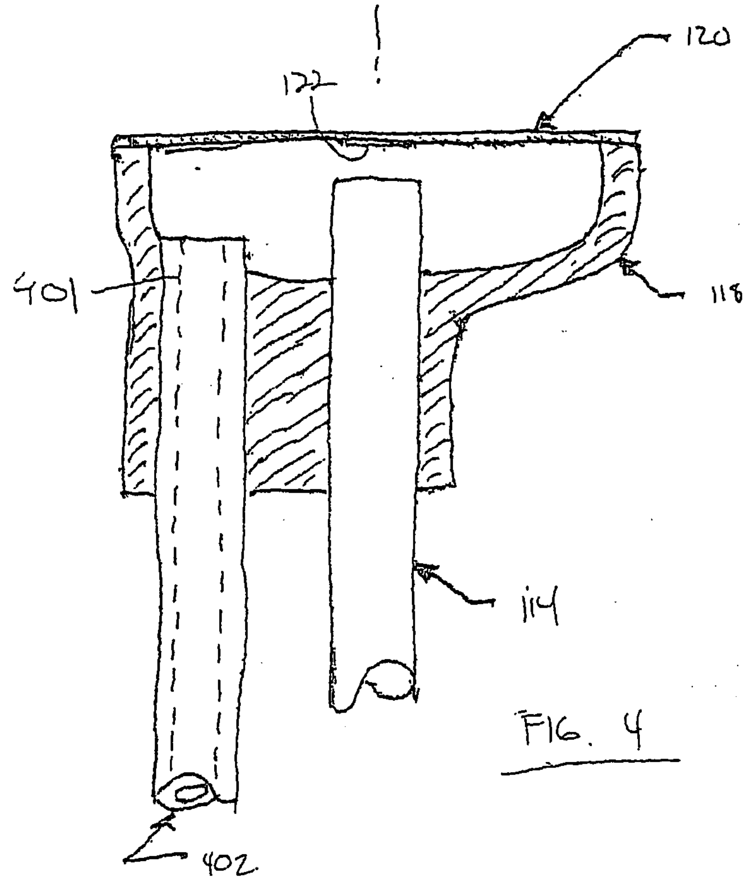


FIG. 4

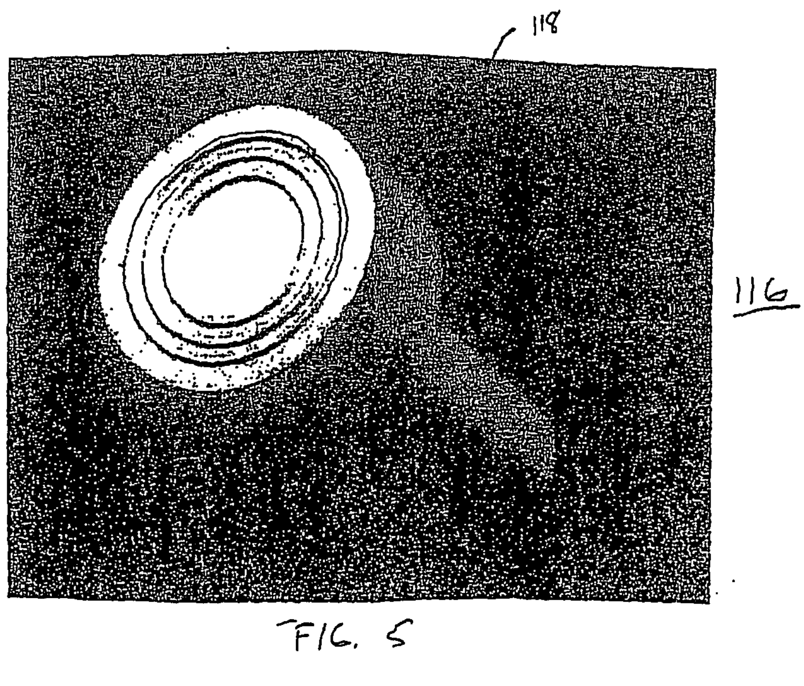


FIG. 5

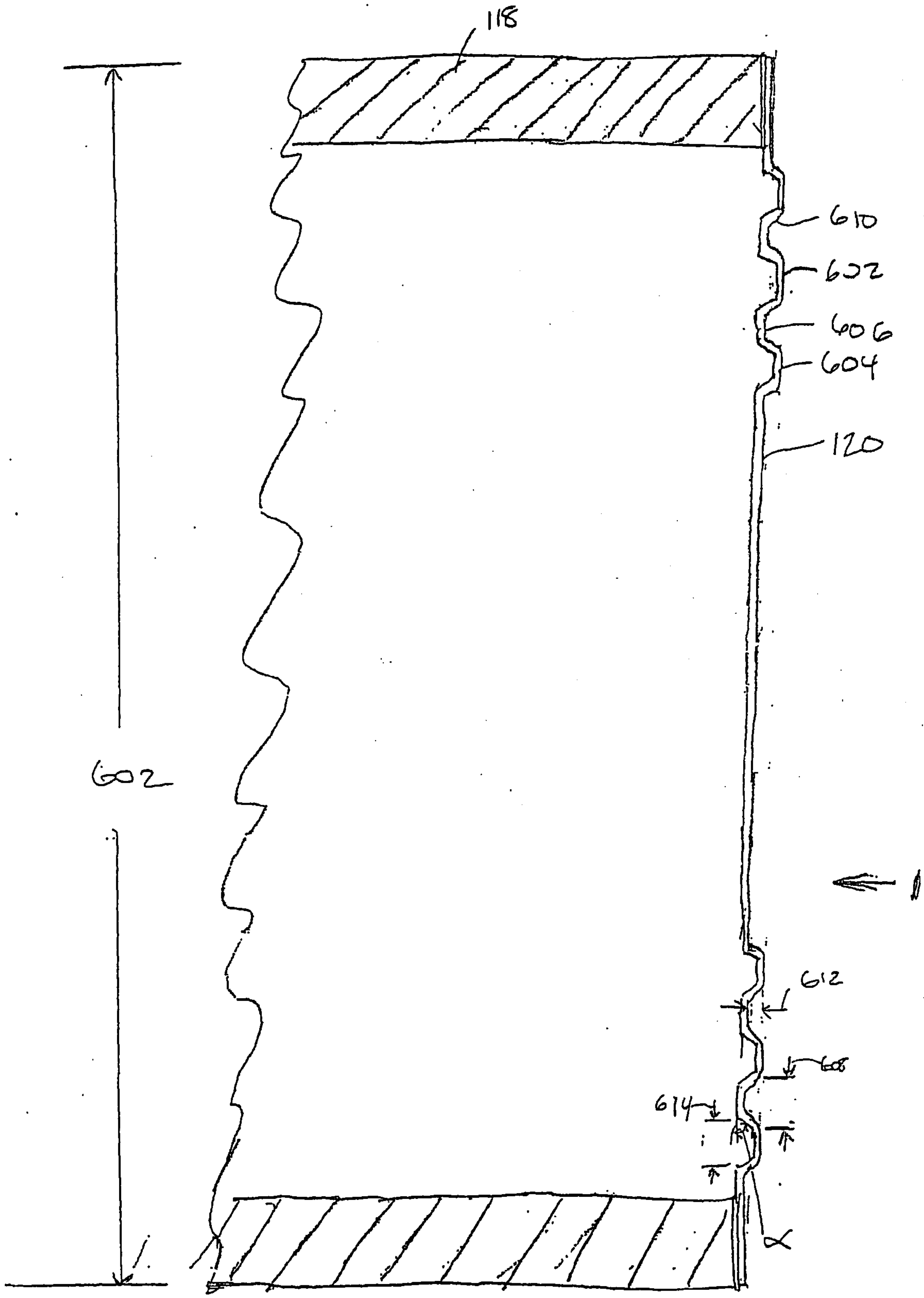


FIG. 6

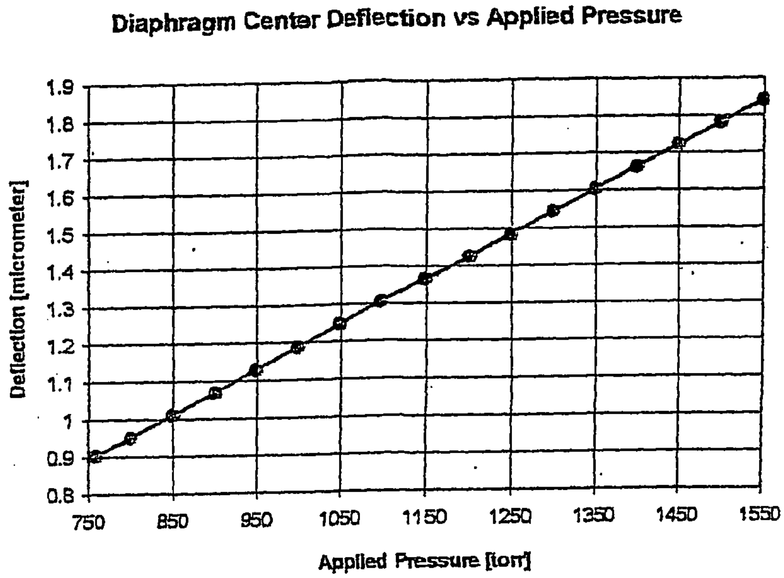

Diaphragm Center Deflection vs Applied Pressure
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
Deflection [micrometer]
750
850
950
1050
1150
1250
1350
1450
1550
Applied Pressure [torr]

FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/42135

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01L9/00 G01L11/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 676 539 A (THOMSON CSF) 20 November 1992 (1992-11-20)	1,2,4,6, 7,9-13, 26,27, 29,30,45
A	the whole document	14-25

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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